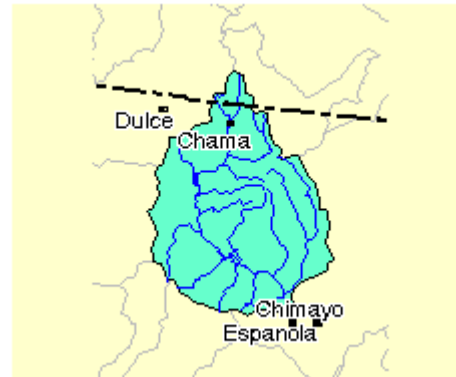
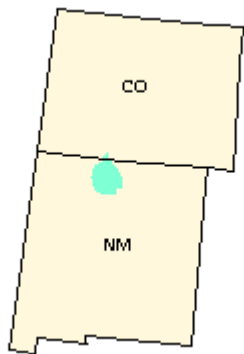


TOTAL MAXIMUM DAILY LOAD FOR TEMPERATURE ON THE RIO CHAMITA



Summary Table

New Mexico Standards Segment	Rio Grande, 2116
Waterbody Identifier	<ul style="list-style-type: none"> Rio Chamita from mouth on the Rio Chama to New Mexico-Colorado border (URG2-30500) <p>Total Waterbody Mileage 12.6 miles Total Affected Mileage ≈12.6 linear miles</p>
Parameters of Concern	Temperature
Uses Affected	High Quality Cold Water Fishery
State Priority	2
Threatened or Endangered Species	None
Geographic Location	Rio Chama River Basin
Scope/size of watershed	38 mi ²
Land type	Southern Rockies Ecoregion
Land use/cover <input type="checkbox"/>	Rangeland 42%, Forest 43%, Colorado 15%, Water <1%
Identified Sources	Rangeland, Removal of Riparian Vegetation, Streambank Modification/Destabilization
Watershed Ownership	68% State Land, 32% Private <input type="checkbox"/>
TMDL for: Temperature Upper Rio Chamita Lower Rio Chamita	<p>WLA + LA + MOS = 0 + 128.70 (joules/meter²/second/day) + 14.3 (joules/meter²/second/day) = 143.00 (joules/meter²/second/day)</p> <p>WLA + LA + MOS = 0 + 125.80 (joules/meter²/second/day) + 13.9 (joules/meter²/second/day) = 139.70 (joules/meter²/second/day)</p>

Table of Contents

EXECUTIVE SUMMARY	iii
LIST OF ABBREVIATIONS	iv
BACKGROUND INFORMATION	1
Figure 1 Rio Chamita Watershed.....	2
ENDPOINT IDENTIFICATION	3
TARGET LOADING CAPACITY	3
Load Allocations	3
Stream Segment and Stream Network Temperature Models	3
Figure 2 Model Components	4
SSOLAR.....	5
SSSHADE	6
SSTEMP.....	8
ASSUMPTIONS AND LIMITATIONS OF THE MODEL	11
THREE MONTH SUMMER MODEL RUN AND TEMPERATURE LOAD ALLOCATIONS	12
IDENTIFICATION AND DESCRIPTION OF POLLUTANT SOURCES	14
LINK BETWEEN WATER QUALITY AND POLLUTANT SOURCES	14
MARGIN OF SAFETY	15
Figure 3 Factors that Impact Water Temperature	16
CONSIDERATION OF SEASONAL VARIATION	17
MONITORING PLAN	17
IMPLEMENTATION	19
MANAGEMENT MEASURES	19
TIME LINE	22
ASSURANCES	22
MILESTONES	23
MEASURES OF SUCCESS	23
PUBLIC PARTICIPATION	24
Figure 4 Public Participation Flowchart	25
APPENDICES	
APPENDIX A THERMOGRAPH/GEOMORPHOLOGICAL DATA AND SITES	
APPENDIX B SSTEMP MODEL OUTPUTS	
APPENDIX C CRITICAL LOW FLOW MODEL OUTPUTS	
APPENDIX D PUBLIC COMMENTS	
REFERENCES CITED	

EXECUTIVE SUMMARY

Section 303(d) of the Federal Clean Water Act requires states to develop TMDL management plans for water bodies determined to be water quality limited. A TMDL documents the amount of a pollutant a water body can assimilate without violating a state's water quality standards. It also allocates that load capacity to known point sources and nonpoint sources. TMDLs are defined in 40 CFR Part 130 as the sum of the individual Waste Load Allocations (WLA) for point sources and Load Allocations (LA) for nonpoint sources, including a margin of safety and natural background conditions.

The Rio Chamita flows from headwaters in Colorado to its confluence with the Rio Chama below the Village of Chama. The New Mexico 1998 §303(d) report, "*State of New Mexico §303(d) List for Assessed Stream and River Reaches*," lists this segment as being water quality limited for the following pollutants: total phosphorous, total ammonia, fecal coliform, temperature, stream bottom deposits, chlorine, and turbidity. Subsequent sampling conducted in three seasons in 1998 resulted in a re-evaluation of these listings. Based on this sampling, the listings were modified to include only total ammonia, total phosphorous, and fecal coliform. This Total Maximum Daily Load (TMDL) document addresses temperature only.

Exceedences of New Mexico water quality standards for temperature were documented on the Rio Chamita from the New Mexico-Colorado border to the confluence with the Rio Chama (12.6 mi.). Over the years, reduced riparian vegetation, including herbaceous woody plants such as willow and alder along the stream, and exceedences in temperature standards have been seen and documented along this reach of North Ponil Creek. Thermograph (temperature monitoring devices) stations were located on upper Rio Chamita at the confluence with Sexto Creek, middle Rio Chamita at Highway 29 Bridge and lower Rio Chamita at the wastewater treatment plant (WWTP) influent channel. This monitoring effort documented 71 exceedences out of a total of 1,752 readings on the upper Rio Chamita, 173 exceedences out of a total of 1,751 readings on the middle Rio Chamita and 254 exceedences out of a total of 1,750 readings on the lower Rio Chamita. This TMDL addresses these exceedences.

A general implementation plan for activities to be established in the watershed is included in this document. The Surface Water Quality Bureau's Point Source Regulation and Nonpoint Source Pollution Sections will further develop the details of this plan. Implementation of recommendations in this document will be done with full participation of all interested and affected parties. During implementation, additional water quality data will be generated. As a result targets will be re-examined and potentially revised; this document is considered to be an evolving management plan. In the event that new data indicate that the targets used in this analysis are not appropriate or if new standards are adopted, the load capacity will be adjusted accordingly.

List of Abbreviations

BMP	Best Management Practice
CFS	Cubic Feet per Second
CMS	Cubic Meters per second
CWA	Clean Water Act
CWAP	Clean Water Action Plan
CWF	Cold Water Fishery
EPA	Environmental Protection Agency
HQCWF	High Quality Cold Water Fishery
LA	Load Allocation
MGD	Million Gallons per Day
mg/L	Milligrams per Liter
MOS	Margin of Safety
MOU	memorandum of understanding
NMED	New Mexico Environment Department
NPDES	National Pollution Discharge Elimination System
NPS	Nonpoint Sources
NTU	Nephelometric Turbidity Units
SNTEMP	Stream Network Temperature Model
SSSHADE	Solar Shading Model
SSSOLAR	Local Solar Radiation Model
SSTEMP	Resulting Stream Temperature Model
SWQB	Surface Water Quality Bureau
TMDL	Total Maximum Daily Load
UWA	Unified Watershed Assessment
WLA	Waste Load Allocation
WQLS	Water Quality Limited Segment
WQCC	New Mexico Water Quality Control Commission
WQS	Water Quality Standards
WWTP	Wastewater Treatment Plant

Background Information

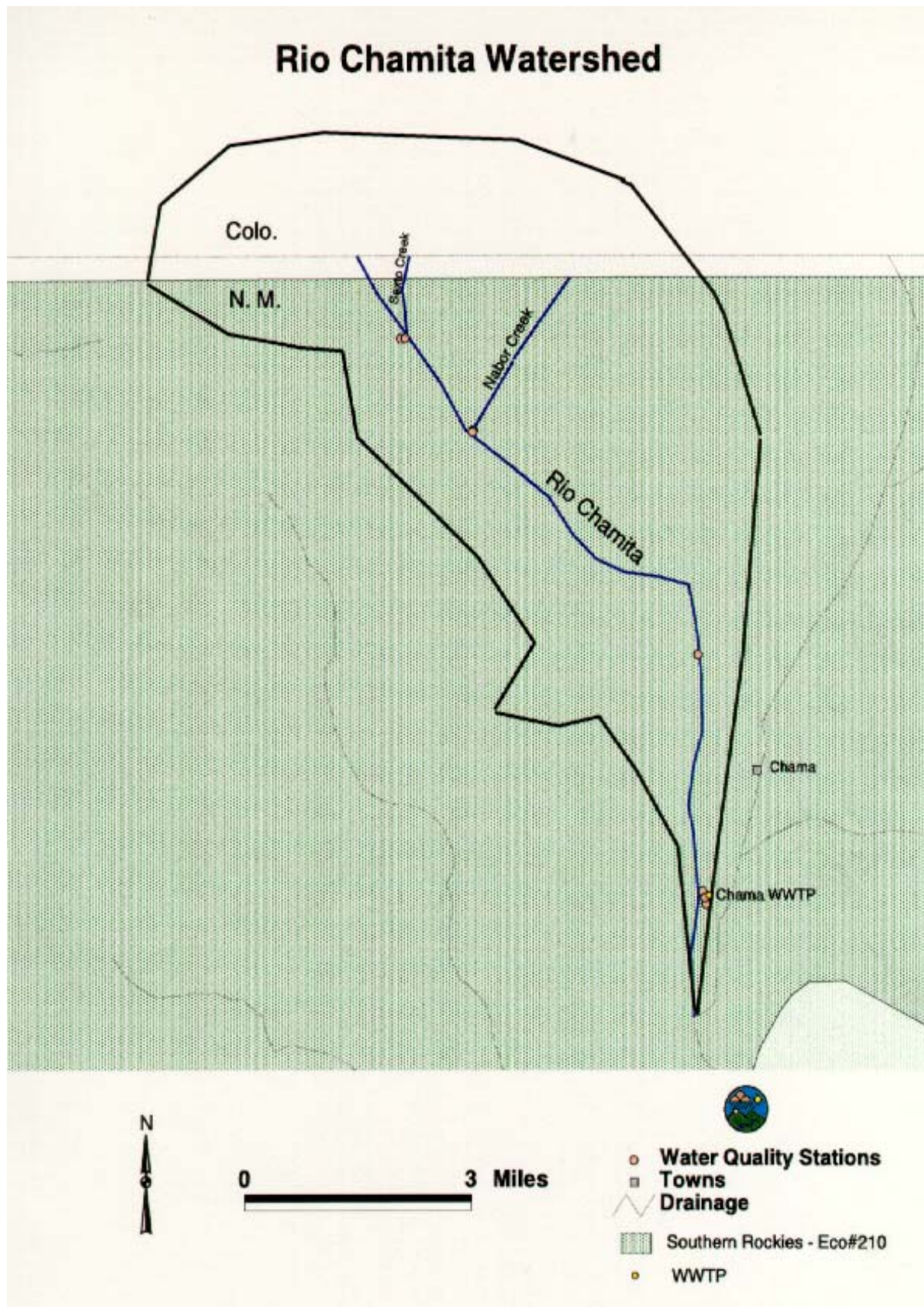
The Rio Chamita flows for approximately 12.6 miles through Rio Arriba County, New Mexico (**Figure 1**). The headwaters of the Rio Chamita arise in Colorado and pass into New Mexico within the approximately 32 square mile Edward Sargent Fish and Wildlife Area. The Rio Chamita then flows along the western side of the Village of Chama to the confluence with the Rio Chama approximately 1.5 miles below the village. Several significant tributaries to the Rio Chamita originate on the Edward Sargent Fish and Wildlife Area. Sexto Creek combines with the Rio Chamita approximately 0.5 miles below the Colorado-New Mexico State boundary. Nabor Creek enters the Rio Chamita 1.5 miles below Sexto Creek. There appear to be significant groundwater inputs to the river, as evidenced in flow monitoring data collected during 1998 sampling, although a thorough study of groundwater flows has not been done. There is no other significant surface water input to the system. The Rio Chamita segment originating in Colorado was found to have no measurable flow above Sexto Creek during both summer and fall sampling events. Flow was observed but not measured during the spring run. The project area (**Figure 1**) in the drainage is approximately 32 square miles, with land use/cover being rangeland 42%, forest 43%, Colorado 15% and water <1%.

Over the years, reduced riparian vegetation, including herbaceous woody plants such as willow and alder along the stream, and exceedences in temperature standards have been seen and documented along the Rio Chamita.

The Rio Chamita from mouth on the Rio Chama to New Mexico-Colorado border is listed in the New Mexico 1998-2000 §303(d) list as not supporting its designated use due to temperature exceedences. Thermograph data shows that all 12.6 miles of the stream is not supporting its designated use due to temperature exceedences. This TMDL is for the entire reach.

Probable sources of nonsupport include: rangeland activities (grazing), removal of riparian vegetation and streambank modification/destabilization.

Figure 1.



Endpoint Identification

Target Loading Capacity

The New Mexico WQCC has adopted numeric water quality standards for temperature to protect the designated use of HQCWF. These water quality standards have been set at a level to protect cold-water aquatic life such as trout. The HQCWF use designation requires that a stream reach must have water quality, stream bed characteristics, and other attributes of habitat sufficient to protect and maintain a propagating coldwater fishery (i.e., a population of reproducing salmonids). The primary standard leading to an assessment of use impairment is the numeric criteria for temperature of 20°C (68°F)¹.

Load Allocations

The Stream Segment and Stream Network Temperature Models²

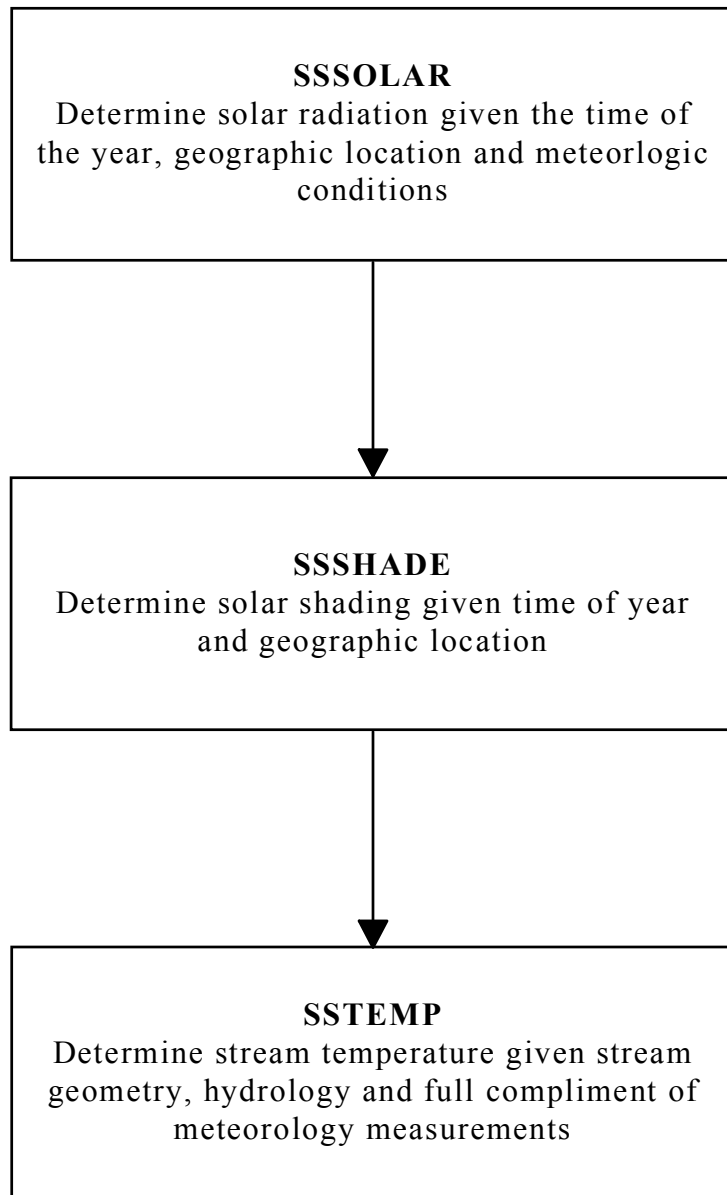
Water temperature can be expressed as heat energy per unit volume. The Stream Segment Temperature Models (SSTEMP) provide an estimate of heat energy per unit volume expressed in Joules (the absolute meter kilogram-second unit of work or energy equal to 10⁷ ergs or approximately 0.7375 foot pounds) per meter squared per second (J/M²/S) and Langleys (a unit of solar radiation equivalent to one gram calorie per square centimeter of irradiated surface) per day.

The SSTEMP programs are currently divided into three related but separable components or submodels. Though technically the programs can be run in any order, for our purposes, we will conceptualize them in a physically based order (**Figure 2**):

¹ New Mexico Water Quality Control Commission, *State of New Mexico Standards for Interstate and Intrastate Streams*, Subpart I - General, Section 1102 (I), p. 5, Subpart III - Definitions and Standards Applicable to Attainable or Designated Uses, Section 3101(C), p. 44.

² US Geological Survey, Biological Resource Division, Midcontinent Ecological Science Center, River Systems Management Section, Fort Collins, CO, 1997. *The Stream Segment and Stream Temperature Models, Version 1.0*, pp. 35-50

Figure 2. Model Components



Determining the Local Solar Radiation (SSSOLAR)³

To parameterize the model, follow the procedure outlined below:

Beginning Month and Day – Enter the number of the month and day which start the time period of interest.

Ending Month and Day – Enter the number of the month and day which end the time period of interest.

Number of Days – The number of days is a factor which tells the program when and how often to sample during the period. If the results are for a single day only, use one day. For periods between a day and a month, 2 days is sufficient. Time periods greater than a month are not recommended.

Latitude (degrees and minutes) – Latitude refers to the position of the stream segment on the earth's surface relative to the equator. It may be read from any standard topographic map. You should enter both degrees and minutes in the spaces provided.

Elevation – Read the mean elevation off of the topographic map.

Air Temperature (°F) – Mean daily air temperature representative of the time period modeled.

Relative Humidity (percent) – Mean daily relative humidity representative of the time period modeled.

Possible Sun (percent) – This variable is an indirect measure of cloud cover. Ten percent cloud cover is 90% possible sun. Estimates are available from the weather service or can be directly measured.

Dust Coefficient – This dimensionless value represents the amount of dust in the air. Representative values are:

Winter	-	6 to 13
Spring	-	5 to 13
Summer	-	3 to 10
Fall	-	4 to 11

If all other variables are known, the dust coefficient may be calibrated by using known ground-level solar radiation data. For the purposes of this model, an intermediate value is sufficient; the model is not very sensitive variable. For example, when modeling summer conditions, entering 6.5 will suffice.

Ground Reflectivity (percent) – The ground reflectivity is a measure of the amount of short wave radiation reflected from the earth back into the atmosphere, and is a function of vegetative cover, snow cover or water. Representative values are:

Meadows and fields	14
Leaf and needle forest	5 to 20
Dark, extended mixed forest	4 to 5

³

US Geological Survey, Biological Resource Division, Midcontinent Ecological Science Center, River Systems Management Section, Fort Collins, CO, 1997. The Stream Segment and Stream Temperature Models, Version 1.0, pp. 37-39

Heath	10
Flat ground, grass covered	15 to 33
Flat ground, rock	12 to 15
Flat ground, tilled soil	15 to 30
Sand	10 to 20
Vegetation, early summer	19
Vegetation, late summer	29
Fresh snow	80 to 90
Old snow	60 to 80
Melting snow	40 to 60
Ice	40 to 50
Water	5 to 15

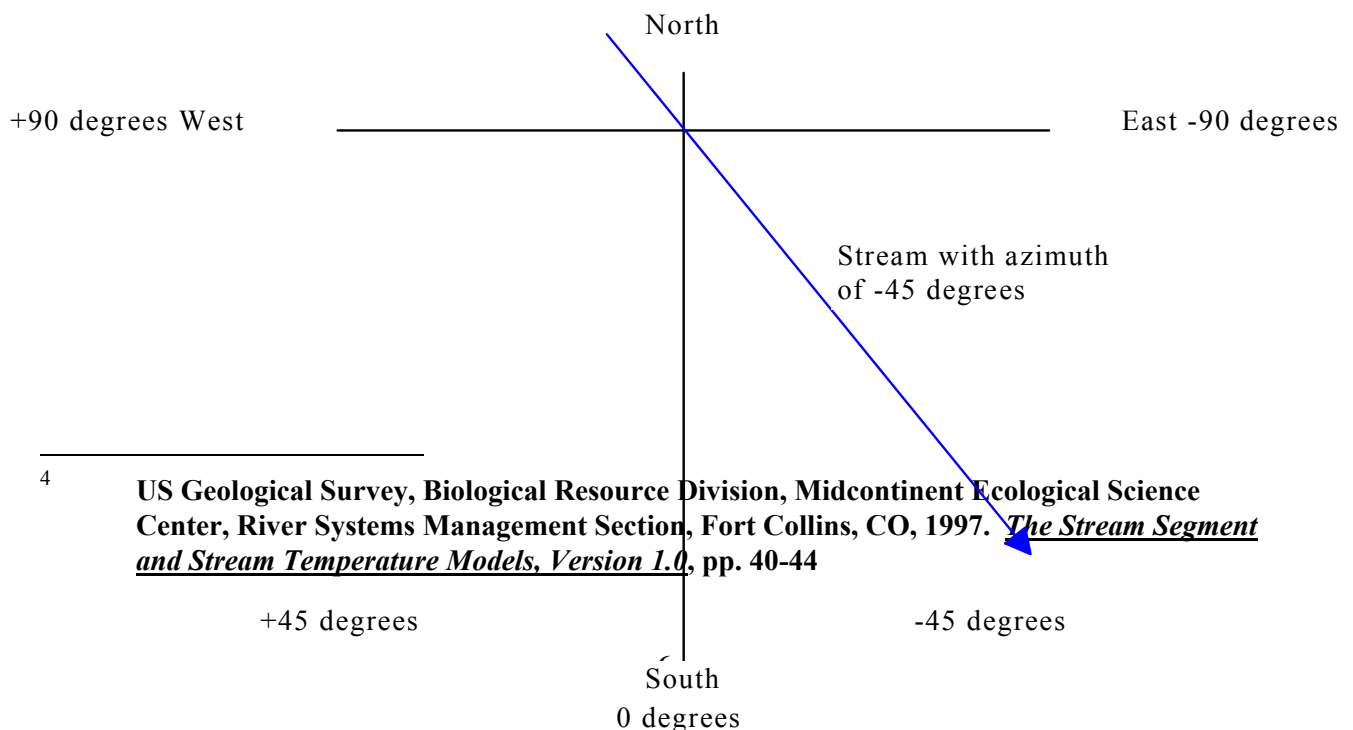
The short wave radiation units are shown in Joules per square meter per second and in Langleys per day. The latter is the common English measurement unit. The values to be carried into **SSTEMP** are the radiation penetrating the water and the daylight hours.

Determining Solar Shading (SSSHADE) ⁴

To parameterize the model, follow the procedure outlined below:

Latitude (degrees and minutes) – Latitude refers to the position of the stream segment on the earth's surface relative to the equator. It may be read from any standard topographic map. You should enter both degrees and minutes in the spaces provided.

Azimuth (degrees) – Azimuth refers to the general orientation of the stream segment with respect to due South and controls the convention of which side of the stream is East or West. A stream running North-South would have an azimuth of 0°. A stream running Northwest-Southeast would have an azimuth of –45 degrees. The direction of flow does not matter. Refer to the following diagram for guidance:



Once the azimuth is determined, usually from the topographic map, the East and West sides are fixed by convention.

Width (feet) – Refer to the average width of the stream from water's edge to water's edge for the appropriate time of the year. Note that the width and vegetative offset should usually be changed in tandem.

Month – Enter the number of the month to be modeled.

Day – Enter the number of the day of the month to be modeled. This program's output is for a single day. To compute an average shade value for a longer period (up to one month) use the middle day of that period. The error will usually be less than one percent.

Topographic Altitude (degrees) – This is a measure of the average incline to the horizon from the middle of the stream. Enter a value for both East and West sides. The altitude may be measured with a clinometer or estimated from topographic maps. In hilly country, topographic maps may suffice.

Vegetative Height (feet) – This is the average height for the shade-producing level of vegetation measured from the water's surface.

Vegetation Crown (feet) – This is the average maximum crown diameter for the shade-producing level of vegetation along the stream.

Vegetation Offset (feet) – This is the average offset of the stems of the shade-producing level of vegetation from the water's edge.

Vegetation Density (percent) – This is the average screening factor (0 to 100%) of the shade-producing level of vegetation along the stream. It is composed of two parts: the continuity of the vegetative coverage along the stream (quantity), and the percent of light filtered by the vegetation's leaves and trunks (quality).

For example, if there is vegetation along 25% of the stream and the average density of that coverage is 85%, the total vegetative density is .25 time .85, which equals .2125, or 21.25%. The value should always be between 0 and 100%.

To give examples of shade quality, an open pine stand provides about 65% light filtering; a closed pine stand provides about 75% light removal; relatively dense willow or deciduous stands remove about 85% of the light; a tight spruce/fir stand provides about 95% light removal. Areas of extensive, dense emergent vegetation should be considered 90% efficient for the surface area covered.

The program will predict the total segment shading for the set of variables you provide. The program will also display how much of the total shade is a result of topography and how much is a result of vegetation. The topographic shade and vegetative shade are added to provide total shade. However, one should think of topographic shade as always being dominant in the sense that topography always intercepts radiation first, then the vegetation intercepts what is left. It is total segment shade that is carried forward into the **SSTEMP** program.

Determine Resulting Stream Temperatures (SSTEMP)⁵

⁵

US Geological Survey, Biological Resource Division, Midcontinent Ecological Science Center, River Systems Management Section, Fort Collins, CO, 1997. *The Stream Segment*

To parameterize the model, follow the procedure outlined below:

Segment Inflow (cfs or cms) – Enter the mean daily flow at the top of the stream segment. If the segment begins at a true headwater, the flow may be entered as zero; all accumulated flow will accrue from lateral (groundwater) inflow. If the segment begins at a reservoir, the flow will be outflow from the reservoir. The model assumes steady-state flow conditions.

Inflow Temperature (°F or °C) – Enter the mean daily water temperature at the top of the segment. If the segment begins at a true headwater, you may enter any water temperature because zero flow has zero heat. If there is a reservoir at the inflow, use the reservoir release temperature. Otherwise, use the outflow temperature from the upstream segment.

Segment Outflow (cfs or cms) – The program calculates the lateral discharge by knowing the flow at the head and tail of the segment, subtracting to obtain the net difference, and dividing by segment length. The program assumes that lateral inflow (or outflow) is uniformly apportioned through the length of the segment. If any “major” tributaries enter the segment, divide the segment into subsections between such tributaries. “Major” is defined as any stream contributing greater than 10% of the mainstem flow.

Lateral Temperature (°F or °C) – The temperature of the lateral inflow, barring tributaries, should be the same as the groundwater temperature. In turn, groundwater temperature is often very close to the mean annual air temperature. This can be verified this by checking USGS well log temperatures. Obvious exceptions may arise in areas of geothermal activity. If irrigation return flows make up most of the lateral flow, they may be warmer than mean annual air temperature. Return flow temperature may be approximated by equilibrium temperatures.

Segment Length (miles or kilometers) – Enter the length of the segment for which you want to predict the outflow temperature.

Manning’s n (dimensionless) – Manning’s n is an empirical measure of the stream’s “roughness.” A generally acceptable default value is 0.035. The variable is necessary only if you are interested in predicting the minimum and maximum daily fluctuation in temperatures. This variable is not used in the prediction of the mean daily water temperature, and the model is not particularly sensitive to it.

Elevation Upstream (feet or meters) – Enter the elevation as taken from a 7-1/2 minute quadrangle map.

Elevation Downstream (feet or meters) – Enter the elevation as taken from a 7-1/2 minute quadrangle topographic map.

Width’s A Term (dimensionless) – This variable may be derived by calculating the wetted width versus discharge relationship. To conceptualize this, plot the width of the segment on the Y-axis and discharge on the X-axis. Three or more measurements are much better than two. The relationship should approximate a straight line, the slope of which is the B term.

Width’s B Term (dimensionless) – The B term is calculated by linear measurements from the above mentioned plot. A good estimate in the absence of anything better is 0.20 (Leopold, 1964).

Thermal Gradient (Joules/Meter²/Second/°C) – This quantity is a measure of the rate of thermal flux from the streambed to the water.

The model is not particularly sensitive to this variable. The default value is 1.65.

Air Temperature (°F or °C) – Enter the mean daily air temperature.

This and the following meteorological variables may come from weather reports which can be obtained for a weather station near the site.

Relative Humidity (percent) – Obtain the mean daily relative humidity for the area by measurement or from the weather service.

Wind Speed (miles/hour or meters/second) – Measure or obtain from the weather service.

Percent Possible Sun (percent) – This variable is an indirect measure of cloud cover. Ten percent cloud cover is 90% possible sun. Estimates are available from the weather service or can be directly measured.

Solar Radiation (Langley/day or Joules/meter²/second) – Enter the results from the SSSOLAR program. If you use a source other than SSSOLAR (such as Cinquemani 1978), you should assume that approximately 93% of the ground-level solar radiation actually enters the water; the rest is assumed to be reflected. Thus, multiply any recorded ground-level solar measurements by 0.93 to calculate the radiation actually entering the water.

Daylight Length (hours) – Adjust the time between sunrise and sunset for the time of year. You may use the SSSOLAR program to calculate this.

Segment Shading (percent) – This variable refers to how much of the segment is shaded by vegetation, cliffs, etc. If 10% of the water surface is shaded, enter 10. To be accurate, the SSSHADE model should be used to predict the actual shading value based on topography, vegetative coverage and vegetative density.

In lieu of using the SSSHADE model, you may think of the shade factor as being the average percent of water surface shaded throughout the day. In actuality, shade represents the percent of the incoming solar radiation that does not reach the water.

Ground Temperature (°F or °C) – Use mean annual air temperature from the weather service.

Dam at Inflow (Yes = 1 No = 0) – If a reservoir is supplying the inflow, enter a 1, otherwise enter a 0.

The maximum daily water temperature is calculated by following a parcel of water from solar noon at the top of the stream segment to the end of the segment, allowing it to heat up towards the maximum equilibrium temperature. If there is an upstream reservoir or spring that is the source of constant temperature water, and the distance upstream is less than the distance traveled by the water parcel from solar noon to the end of the segment, the water parcel from the dam's discharge is heated instead of the water parcel a full half day's travel upstream. The stream segments meteorology and geometry supplied as variables will apply to the distance upstream through which the water column travels.

The program will predict the 24-hour minimum, mean and maximum daily water temperature for the set of variables provided. The theoretical basis for the model is strongest for the mean daily temperature. The maximum daily temperature varies as a function of several different factors. The mean daily equilibrium temperature is that temperature which the mean daily water temperature will approach if all conditions remain the same as the water parcel travels downstream.

Of course, all conditions cannot remain the same, since the elevation changes immediately.

The maximum daily equilibrium temperature is that temperature which the maximum daily water temperature will approach.

Other results include the intermediate variables average width, average depth and slope, calculated from the twenty input variables, and the heat flux components. These heat flux components are abbreviated in the program's output as follows:

ATM	=	atmospheric component
CVN	=	convection component
CDN	=	conduction component
EVP	=	evaporation component
FRC	=	friction component
SOL	=	solar radiation component
VEG	=	vegetative radiation component
WAT	=	water's back radiation component

Assumptions and Limitations⁶

There are several assumptions that apply to SNTEMP. These assumptions in turn dictate the limitations in terms of model applications.

First, SNTEMP is a steady state model. It assumes that the conditions being simulated involve only steady flow – no hydropeaking can be simulated unless the flows are essentially constant for the entire averaging period. The minimum average period is one day. Similarly, the boundary conditions of SNTEMP are assumed homogeneous and constant. This has implications for the maximum size of the network simulated for a single averaging period.

Second, SNTEMP assumes homogeneous and instantaneous mixing wherever two sources of water are combined. There is no lateral or vertical temperature distribution (or dispersion/diffusion), represented in the model.

Third, SNTEMP itself is meant solely for stream temperature predictions. It will not handle stratified reservoirs, though river-run reservoirs with equilibrium releases may be simulated.

Fourth, SNTEMP is not a hydrology model. It should be relied on to distribute flows in an ungaged network. That is often an additional, non-temperature model task.

Fifth, SNTEMP may not be reliable in very cold conditions, i.e., water temperatures less than 4°C. It is not meant for ice or the like.

Finally, SNTEMP and SSTEMP have been tested only in the northern hemisphere

Temperature Allocations as Determined by Percent (%) Shade

The following tables show outputs of the three-month model run from June 1 through August 31 on Upper Rio Chamita and Lower Rio Chamita respectively. As the % total shade is increased, the maximum 24-hour temperature decreases until the HQCWF standard (20°C, 68°F) is achieved. On Upper Rio Chamita, this occurs when the % total shade of the model is 57 and higher. The actual load allocation (LA) of 128.7 joules/meter²/second is achieved at 62% shade or higher according to the model runs. On Lower Rio Chamita, this occurs when the % total shade of the model is 58 and higher. The actual load allocation (LA) of 125.8 joules/meter²/second is achieved at 63% shade or higher according to the model runs.

⁶ US Geological Survey, Biological Resource Division, Midcontinent Ecological Science Center, River Systems Management Section, Fort Collins, CO, 1997. *The Stream Segment and Stream Temperature Models, Version 1.0*, pp. 26-27

Three Month Summer Model Run On Upper Rio Chamita June Through August

Rosgen Channel Class	WQS (HQCWF)	Model Run Dates	Segment Length (mi)	Solar Radiation Component per 24-Hours (+/-)	% Total Shade	% Topo Shade	% Veg Shade	Temperature °F (24 hour)		Temperature °C (24 hour)	
E4 Stream Type	20°C (68°F)	June 1 thru Aug 31	6	Current Field Condition +196.3 joules/meter ² /second	41	2	39	Minimum Mean Maximum	53.53 62.59 71.66	Minimum Mean Maximum	11.96 16.99 22.03
<p>Stream Segment Temperature Model (SSTEMP)</p> <p>TEMPERATURE ALLOCATIONS AS DETERMINED BY % SHADE ON UPPER RIO CHAMITA</p> <p>* DENOTES 24 HOUR ACHIEVEMENT OF SURFACE WATER QUALITY STANDARD FOR TEMPERATURE</p> <p>Actual Reduction in Solar Load to this Stream to meet the State surface water quality standard is:</p> <p>196.3 joules/meter²/second (current condition) – 128.7 joules/meter²/second (60% shaded water) = 67.60 joules/meter²/second</p> <p>♦ Denotes the achievement of the 128.7 joules/meter²/second load allocation (LA)</p>				+179.6 joules/meter ² /second	46	2	44	Minimum Mean Maximum	53.32 61.91 70.50	Minimum Mean Maximum	11.84 16.62 21.39
				+166.3 joules/meter ² /second	50	2	48	Minimum Mean Maximum	53.16 61.36 69.56	Minimum Mean Maximum	11.76 16.31 20.87
				+149.7 joules/meter ² /second	55	2	53	Minimum Mean Maximum	52.97 60.67 68.36	Minimum Mean Maximum	11.65 15.93 20.20
				+146.4 joules/meter ² /second	56	2	54	Minimum Mean Maximum	52.93 60.53 68.12	Minimum Mean Maximum	11.63 15.85 20.07
				*+143.0 joules/meter ² /second	57	2	55	Minimum Mean Maximum	52.90 60.39 67.88	Minimum Mean Maximum	11.61 15.77 19.93
				♦+128.7 joules/meter ² /second	62	2	60	Minimum Mean Maximum	52.72 59.68 66.64	Minimum Mean Maximum	11.51 15.38 19.24

Three Month Summer Model Run On Lower Rio Chamita June Through August

Rosgen Channel Class	WQS (HQCWF)	Model Run Dates	Segment Length (mi)	Solar Radiation Component per 24-Hours (+/-)	% Total Shade	% Topo Shade	% Veg Shade	Temperature °F (24 hour)		Temperature °C (24 hour)	
B3c Stream Type	20°C (68°F)	June 1 thru Aug 31	6	Current Field Condition +213.1 joules/meter ² /second	36	7	30	Minimum Mean Maximum	52.11 62.59 73.08	Minimum Mean Maximum	11.17 16.99 22.82
<p>Stream Segment Temperature Model (SSTEMP)</p> <p>TEMPERATURE ALLOCATIONS AS DETERMINED BY % SHADE ON LOWER RIO CHAMITA</p> <p>* DENOTES 24 HOUR ACHIEVEMENT OF SURFACE WATER QUALITY STANDARD FOR TEMPERATURE</p> <p>Actual Reduction in Solar Load to this Stream to meet the State surface water quality standard is:</p> <p>213.1 joules/meter²/second (current condition) – 125.80 joules/meter²/second (61% shaded water) = 87.30 joules/meter²/second</p> <p>♦ Denotes the achievement of the 125.8 joules/meter²/second load allocation (LA)</p>				+199.7 joules/meter ² /second	40	7	33	Minimum Mean Maximum	51.99 62.09 72.18	Minimum Mean Maximum	11.11 16.72 22.32
				+183.1 joules/meter ² /second	45	7	38	Minimum Mean Maximum	51.86 61.45 71.04	Minimum Mean Maximum	11.03 16.36 21.69
				+166.5 joules/meter ² /second	50	7	43	Minimum Mean Maximum	51.74 60.80 69.86	Minimum Mean Maximum	10.97 16.00 21.03
				+149.8 joules/meter ² /second	55	7	48	Minimum Mean Maximum	51.63 60.15 68.66	Minimum Mean Maximum	10.91 15.64 20.37
				*+139.8 joules/meter ² /second	58	7	51	Minimum Mean Maximum	51.57 59.75 67.92	Minimum Mean Maximum	10.87 15.42 19.96
				♦+125.8 joules/meter ² /second	63	7	56	Minimum Mean Maximum	51.49 59.08 66.68	Minimum Mean Maximum	10.83 15.04 19.27

Identification and Description of Pollutant Source(s)

Pollutant Sources	Magnitude	Location
Point: 0	0	NA
Nonpoint:	57%	Upper Rio Chamita
	58%	Lower Rio Chamita
MOS	10% 10%	Upper Rio Chamita Lower Rio Chamita

Link Between Water Quality and Pollutant Sources

Decreased effective shade levels result from reduction of riparian vegetation. This leads to increased incident solar radiation on the water surface and therefore increased energy loading. Wider stream channels also increase the stream surface area exposed to sunlight and heat transfer. Riparian area and channel morphology disturbances are attributed to past and to some extent current rangeland grazing practices which have resulted in reduction of riparian vegetation and streambank destabilization. These nonpoint sources of pollution primarily affect the water quality parameter temperature through increased solar loading by: (1) increasing stream surface solar radiation and loading and (2) increasing stream surface area exposed to solar radiation loading. **(Figure 3)**

Riparian vegetation, stream morphology, hydrology, climate and geographic location and aspect influence stream temperature. Although climate and geographic location and aspect are outside of human control, the condition of the riparian area, channel morphology and hydrology can be affected by land use activities. Specifically, the elevated summertime stream temperatures attributable to anthropogenic causes in the Rio Chamita Watershed result from the following conditions:

1. Channel widening (increased width to depth ratios) increases the stream surface area exposed to incident solar radiation,
2. Riparian vegetation disturbance reduces stream surface shading, riparian vegetation height and density,
3. Reduced summertime base flows that result from instream withdrawals. Base flows are maintained with a functioning riparian system so that loss of riparian will lower and sometimes eliminate base flows.

Analysis presented in this TMDL will demonstrate that defined loading capacities will

ensure attainment of State water quality standards.

Specifically, the relationship between shade, solar radiation, and water quality attainment will be demonstrated. Vegetation density increases will provide necessary shading, as well as encourage bank building processes in severe hydrologic events.

Margin of Safety (MOS)

The federal Clean Water Act (CWA) requires that each TMDL be calculated with a margin of safety (MOS). This statutory requirement that TMDLs incorporate a MOS is intended to account for uncertainty in available data or in the actual effect controls will have on loading reductions and receiving water quality. A MOS may be expressed as unallocated assimilative capacity or conservative analytical assumptions used in establishing the TMDL (e.g., derivation of numeric targets, modeling assumptions or effectiveness of proposed management actions).

The MOS may be implicit, utilizing conservative assumptions for calculation of the loading capacity, WLAs and LAs. The MOS may also be explicitly stated as an added separate quantity in the TMDL calculation.

In the development of this temperature TMDL, the following conservative assumptions were used to parameterize the model:

- Warmest time of the year was used in the modeling due to the seasonality of temperature exceedences (June 1 through August 31).

The average 1998 monthly ambient air temperatures for June, July and August

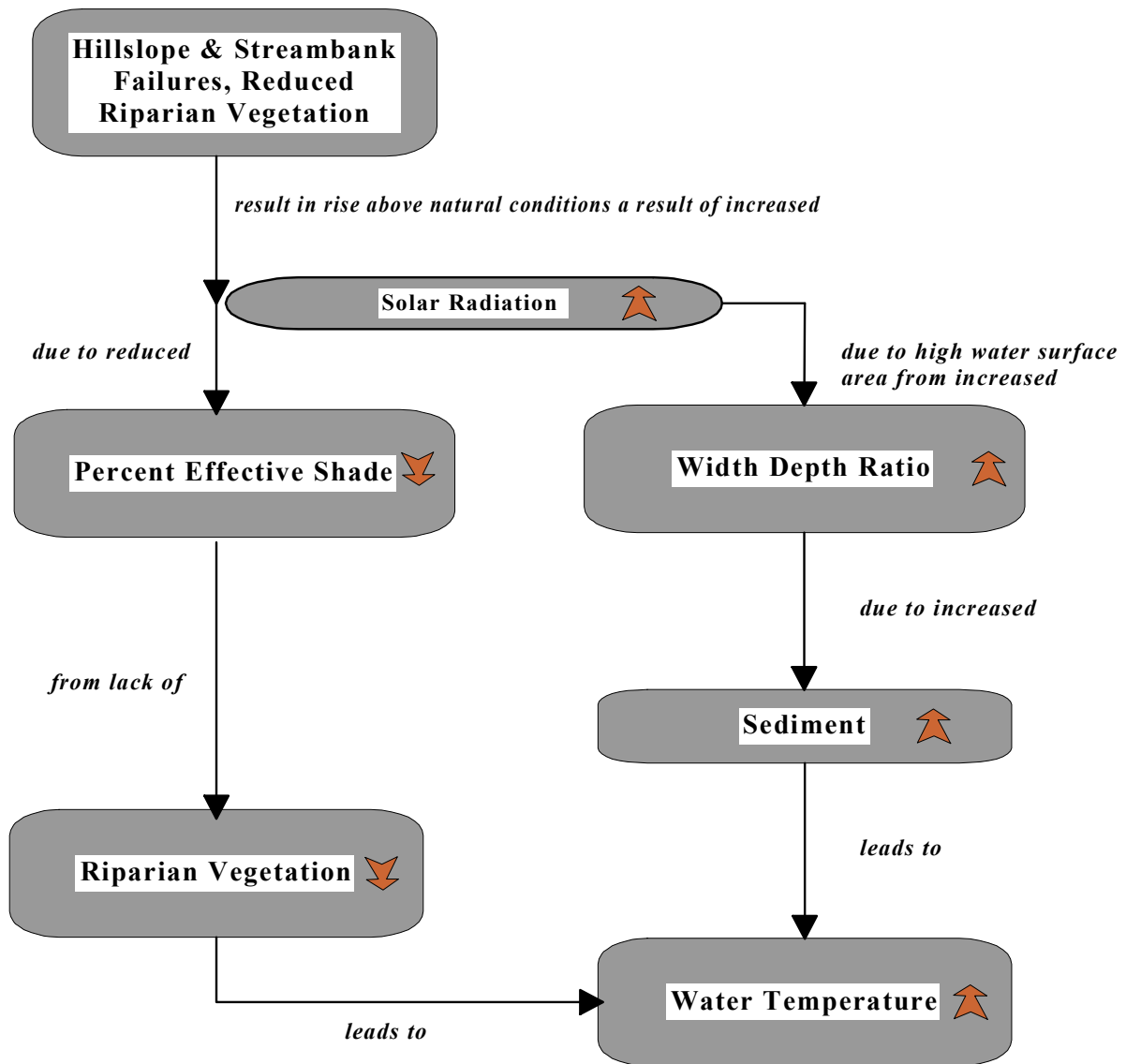
An upstream thermograph was deployed to document the mean daily water temperature above the project site

Actual elevation and latitude/longitude were determined by using a global positioning system (GPS) at the site

- Critical upstream and downstream low flows were used due to the decreased assimilative capacity of the stream to absorb and disperse solar heat at these flows

Low flow was modeled using two formulas developed by the USGS. One formula (Waltemeyer 1987) is recommended when the ratio between the two watershed areas is between 0.5 and 1.5. The other formula, to be used when the watershed ratio is outside this range, is a regression formula also developed by the USGS (Borland 1970).

Figure 3. Factors that Impact Water Temperature



- Stream channel geomorphology was used to determine the level of functionality of the stream along with other physical field measurements that were used in the modeling process

Actual wetted-width of the stream was used

Actual stream channel type was characterized as an “E” channel on the upper site and a “B” channel on the lower site

- Response of receiving waters under various allocation scenarios

Different shading scenarios were used to show the decrease in water temperatures at the critical low flow (See tables)

- Expression of analysis results in ranges

Analysis results provide a range of temperature outputs (See tables)

Because of the high quality of data and information that was put into this model and the continuous field monitoring data used to verify these model outputs, an explicit MOS of 10% is assigned to this TMDL.

Consideration of Seasonal Variation

Section 303(d)(1) of the CWA requires TMDLs to be “established at a level necessary to implement the applicable water quality standard with seasonal variation.” Both stream temperature and flow vary seasonally and from year to year. Water temperatures are coolest in winter and early spring months.

Thermograph records show that temperatures exceed State water quality standards in summer and in early fall on the Rio Chamita. Warmest stream temperatures corresponded to prolonged solar radiation exposure, warm air temperature and low flow conditions. These conditions occur during late summer and early fall and promote the warmest seasonal instream temperatures.

Monitoring Plan

Pursuant to Section 106(e)(1) of the CWA, the SWQB has established appropriate monitoring methods, systems and procedures in order to compile and analyze data on the quality of the waters of New Mexico. In accordance with the New Mexico Water Quality Act, the SWQB has developed and implemented a comprehensive water quality monitoring strategy for the surface waters of the State. The monitoring strategy establishes the methods of identifying and prioritizing water quality data needs, specifies procedures for acquiring and managing water quality data, and describes how these data are used to progress toward three basic monitoring objectives: to develop water quality-based controls, to evaluate the effectiveness of controls and to conduct water quality assessments. In order to optimize the

efficiency of this monitoring effort necessary to support the development of TMDLs, the SWQB has adopted a rotating basin monitoring strategy. This strategy selects a number of watersheds which are intensively monitored each year with an established return frequency. The actual watersheds monitored in any given year will be determined as a function of the priorities specified below.

Current priorities for monitoring in the SWQB are determined by utilizing the following documents:

- §303(d) consent decree (*Forest Guardians and Southwest Environmental Center v. Carol Browner, Administrator, U.S. Environmental Protection Agency*, Civil Action No. 96-0826 LH/LFG)
- §303(d) settlement agreement MOU
- Clean Water Action Plan (CWAP) which includes the Unified Watershed Assessment (UWA)

Short-term efforts will be directed toward those waters which are on the EPA TMDL consent decree list and which are due within the first two years of the consent decree schedule. Once assessment monitoring is completed those reaches still showing impacts and requiring a TMDL will be targeted for more intensive monitoring. Methods of data acquisition include fixed-station monitoring, intensive surveys of priority water bodies including biological assessments, and compliance monitoring of industrial, federal and municipal dischargers.

Long term monitoring for assessments will be accomplished through the establishment of sampling sites that are representative of the waterbody and which can be revisited every five years.

This information will provide time relevant information for use in 305(b) assessments and to support the need for developing TMDLs.

The approach provides:

- an unbiased assessment of the waterbody and establishes a long term monitoring record for trend analyses.
- a systematic, detailed review of water quality data and allows for a more efficient use of resources.
- information at a scale useful to the implementation of corrective activities.
- an established order of rotation and predictable sampling in each basin. This allows easier coordination efforts with other programs and water quality entities.
- Enhanced program efficiency and improved basis for management decisions.

It should be noted that a basin will not be ignored during its 4 year intensive sampling hiatus. The sampling program is supplemented with other data collection efforts which are classified as field studies. The 4-year interim will be used to analyze data, conduct field studies to further characterize identified problems, and develop TMDLs and implement corrective actions. Both types of monitoring, long term and field studies, contribute to the 305(b) report and 303(d) listing processes.

The SWQB maintains current quality assurance and quality control plans to cover all monitoring activities. This document **"Quality Assurance Project Plan for Water Quality Management Programs"** is updated and certified annually by US EPA Region 6. In addition, the SWQB identifies the data quality objectives required to provide information of sufficient quality to meet the established goals of the program.

The following draft schedule is a draft for sampling seasons through 2002 and will be done in a consistent manner to support the New Mexico Unified Watershed Assessment (UWA) and the Nonpoint Source Management Program. This sampling regime will reflect seasonal variation and includes sampling in spring, summer, and fall for each of the watersheds.

- 1998 - Jemez, Chama (above El Vado), Cimarron (above Springer), Santa Fe River, San Francisco
- 1999 - Chama (below El Vado), Middle Rio Grande, Gila River Watershed, Red River Watershed
- 2000 - Mimbres Basin, Dry Cimarron Basin, Upper Pecos (Ft. Sumner to headwaters), Upper Rio Grande (1)
- 2001 - Upper Rio Grande (2), Lower Pecos (Roswell south), Closed Basins, Zuni Watershed
- 2002 - Canadian Basin, Lower Rio Grande, San Juan River Basin, Rio Puerco Watershed

Implementation Plan

Management Measures

Management measures are "economically achievable measures for the control of the addition of pollutants from existing and new categories and classes of nonpoint sources of pollution, which reflect the greatest degree of pollutant reduction achievable through the application of the best available nonpoint pollution control practices, technologies, processes, siting criteria, operating methods, or other alternatives" (USEPA, 1993). A combination of best management practices (BMPs) will be used to implement this TMDL.

Stakeholder and public outreach and involvement in the implementation of this TMDL will be ongoing. Stakeholder participation will include both choosing and installing BMPs, as well as participation in volunteer monitoring.

Implementation of this TMDL will consist of three main phases:

1. Temperature baseline verification monitoring
2. BMP implementation
3. Effectiveness monitoring

1. Temperature Baseline Verification Monitoring

Temperature baseline verification monitoring began July 20, 1998 and ran until October 1, 1998. Thermographs were set to read every hour in order to document diurnal fluctuations in the system. This verification monitoring consists of baseline data collection, verification of current conditions including identification of priority sites for BMP implementation and identification of monitoring locations which will be necessary in order to accurately measure improvements.

SWQB has conducted the following baseline verification monitoring activities as part of this phase:

- Establishment of photo documentation points
- Establishment of monitoring sites
- Collection of baseline data including water chemistry, TDS, TSS, turbidity, DO, anion/cation, conductivity, temperature, canopy density (stream shade), cross channel profiles, pebble count, percent fines and embeddedness.

Once baseline verification monitoring has been completed, the BMP implementation phase will begin.

2. Potential Rio Chamita Project BMPs and their Anticipated Contribution to Load Reduction

- 1) **Riparian Revegetation (plantings)**
Increased canopy cover, stream shade and streambank soil stability. Decreased peak water temperatures, decreased width to depth ratios, a trend toward aggradation of the channel and stream access to the floodplain. Riparian Plantings will consist of native willow, Coyote Willow (*Salix exigua*), Black Willow (*Salix gooddingii*) and Alder (*Alnus tenuifolia*) plantings or containerized stock.
- 2) **Riparian Fencing**
Protection for heavily impacted areas and/or newly rehabilitated segments. Increased revegetation success and streambank soil stability. Decreased TSS and turbidity.
- 3) **Streambank Modification/Channel Reconstruction**

Accelerated healing of banks, restoration of sinuosity patterns, reduced erosion and sedimentation originating from raw streambanks.

This project on the Rio Chamita will potentially result in approximately 5-10 linear miles of revegetation. Final priorities concerning riparian fencing, streambank/channel modification will be made following baseline verification monitoring. SWQB will encourage public/private land owners and volunteers to become involved and assist in all phases of the implementation process.

3. BMP Effectiveness Monitoring

The currently approved QAPP and Nonpoint Source (NPS) Standard Operating Procedures (SOP) methods will be used for all sampling and monitoring for this project. In order to estimate BMP effectiveness, monitoring efforts will focus on the appropriate physical components of the stream system.

The following physical parameters will be monitored in order to evaluate the effectiveness of BMP's:

- **Cross Channel Profiles**
These profiles will be established in key locations to measure changes in channel morphology and width:depth ratios. Natural stream channel stability is achieved by allowing the river to develop a stable dimension, pattern and profile such that, over time, channel features are maintained and the stream system neither aggrades nor degrades.
- **Riparian Canopy Densities**
Density will be measured at fixed locations to determine quantifiable differences in stream shade.
- **Photo Documentation Points**
Photographs will be used to evaluate the success of revegetation efforts and to document changes in channel morphology.

It is recognized that measurable changes in these parameters will require some time occur. Accordingly, monitoring activities will continue until changes in the temperature of this reach of the Rio Chamita have demonstrated the effectiveness of the BMPs.

Time Line

Implementation Action	Year 1	Year 2	Year 3	Year 4	Year 5
Public Outreach and Involvement	X	X	X	X	X
Establish Milestones	X				
Secure Funding	X		X		
Implement Management Measures (BMPs)		X	X		
Monitor BMPs		X	X	X	
Determine BMP Effectiveness				X	X
Re-evaluate Milestones				X	X

Assurances

New Mexico's Water Quality Act does not contain enforceable prohibitions directly applicable to nonpoint sources of pollution. The Act does authorize the Water Quality Control Commission to "promulgate and publish regulations to prevent or abate water pollution in the state" and to require permits. Several statutory provisions on nuisance law could also be applied to nonpoint source water pollution.

Nonpoint source water quality improvement work utilizes a voluntary approach. This provides technical support and grant money for the implementation of best management practices and other NPS prevention mechanisms through §319 of the Clean Water Act. Since this TMDL will be implemented through NPS control mechanisms the New Mexico Nonpoint Source Program is targeting efforts to this and other watersheds with TMDLs. The Nonpoint Source Program coordinates with the Nonpoint Source Taskforce. The Nonpoint Source Taskforce is the New Mexico statewide focus group representing federal and state agencies, local governments, tribes and pueblos, soil and water conservation districts, environmental organizations, industry, and the public.

This group meets on a quarterly basis to provide input on the Section 319 program process, to disseminate information to other stakeholders and the public regarding nonpoint source issues, to identify complementary programs and sources of funding, and to help review and rank Section 319 proposals.

In order to ensure reasonable assurances for implementation in watersheds with multiple landowners, including Federal, State and private land, NMED has established MOUs with different Federal agencies, in particular the Forest Service and the Bureau of Land Management. MOUs have also been developed with other State agencies, such as the New Mexico Highway Department. These MOUs provide for coordination and consistency in dealing with nonpoint source issues.

New Mexico's Clean Water Action Plan has been developed in a coordinated manner with the

State's 303(d) process. All Category I watersheds identified in New Mexico's Unified Watershed Assessment process are totally coincident with the impaired waters list for 1996 and 1998 approved by EPA. The State has given a high priority for funding assessment and restoration activities to these watersheds.

The time required to attain standards in this case is estimated to be 10 years. Standards attainment is predicated on the following growth rates of the riparian species as follows:

<u>Plant Species</u>	<u>Predicted Time to Maturity (years)</u>
Coyote Willow (<i>Salix exigua</i>)	1-3
Black Willow (<i>Salix gooddingii</i>)	1-3
Alder (<i>Alnus tenuifolia</i>)	3-5

Milestones

Milestones will be used for determining if BMP's are being implemented and standards attained. For this TMDL several milestones will be established as follows:

Education/Outreach Milestone

Implement outreach programs for schools, educators, citizens, government officials, landowners, land managers, resource professionals and agency representatives.

Grazing/Rangeland Milestones

Demonstrate rotational grazing and other grazing/wildlife management systems. Implement projects on federal, State and private lands for riparian restoration with improved grazing/wildlife management.

Agriculture Milestones

Implement erosion control BMPs.

Measures of Success:

- Improved bank stability and vegetation stability by increasing root systems thus decreasing sediment inputs into the system and improving canopy densities. Measurement tools include but are not limited to pebble counts, embeddedness, % fines, canopy densities and root density estimates.
- Increased stream shade. Measurement tool spherical densiometer readings.
- Measurable reductions in TSS and peak turbidity. Measurement tools include but are not limited to pebble counts, embeddedness,

- % fines, turbidity readings and lab analyses.
- Increased interagency cooperation via communications with the land management agencies, soliciting their input into the process.
- Increased public participation via pre-monitoring and post-monitoring meetings.

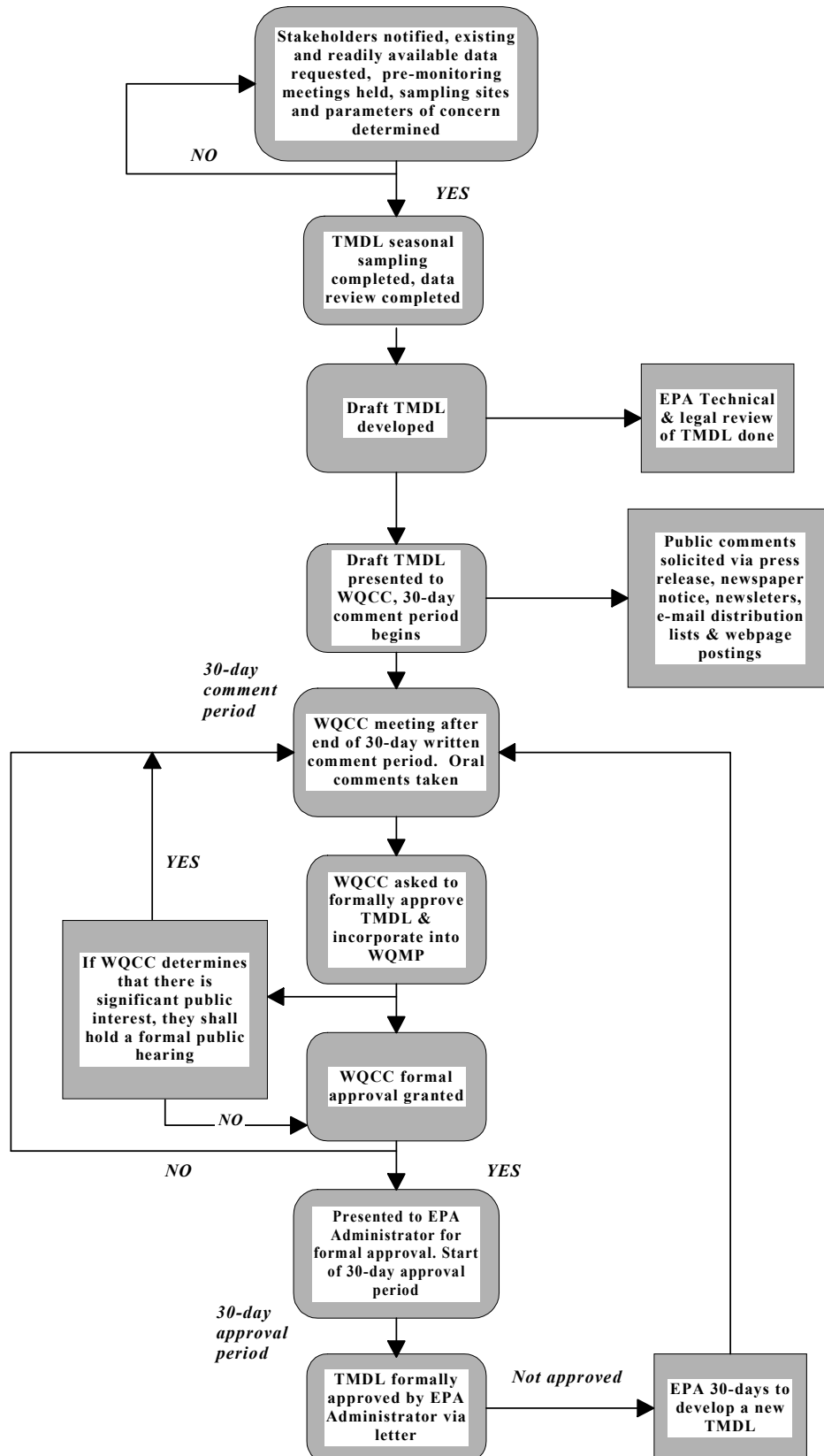
Expanded water quality database and understanding of the relationships between traditional management activities and NPS pollution.

- Increased interagency agreement in determining BMP application and suitability.
- Appropriateness of milestones will be re-evaluated periodically, depending on the BMPs that were implemented. Further implementation of this TMDL will be revised based on this re-evaluation.

Public Participation

The purpose of public participation is to involve all of the interested stakeholders from the start of the process. This requires the sharing of results from the sampling efforts and an indication of what TMDLs will be necessary, along with the implementation plans of these TMDLs (**Figure 4**). Public comments and responses can be found in *Appendix D* of this document. The draft document notice of availability was extensively advertised via newsletters, email distribution lists, webpage postings (<http://www.nmenv.state.nm.us>), and press releases to area newspapers.

Figure 4. Public Participation Flowchart

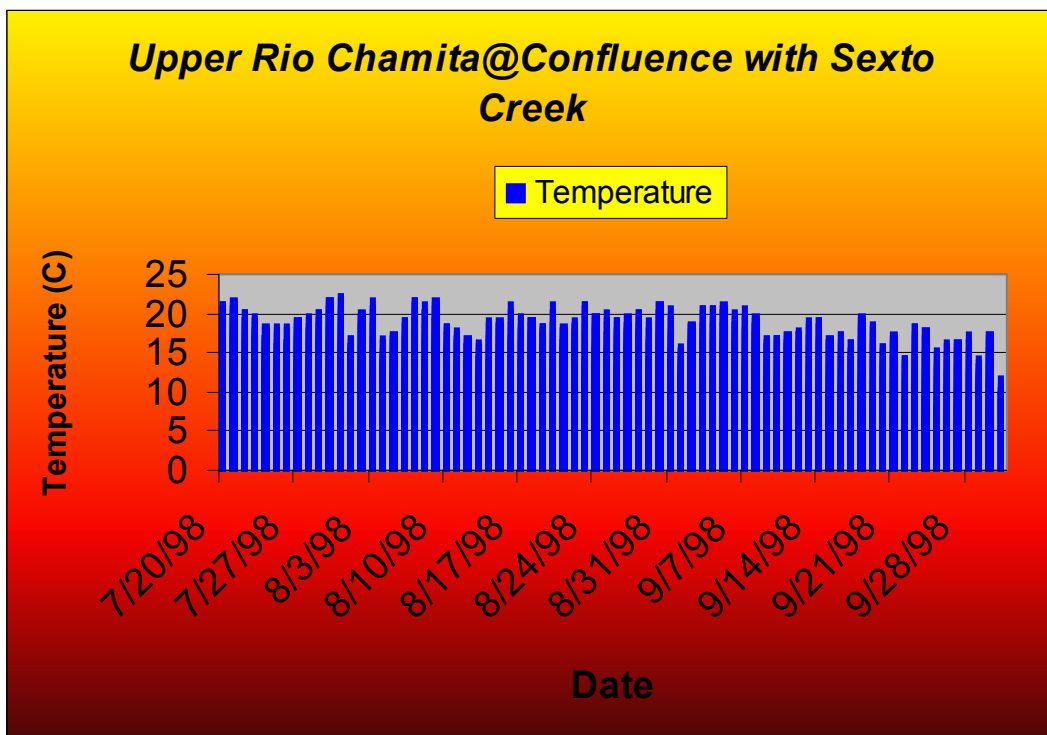


Appendices

Appendix A Thermograph/Geomorphological Data and Sites

Upper Rio Chamita Thermograph Data

Total Readings	1752
Max. Temp.	22.5
# Values>20	71
% Values>20	4.1
Avg. Temp.	14.1
Min. Temp.	3.5
Variance	12.5

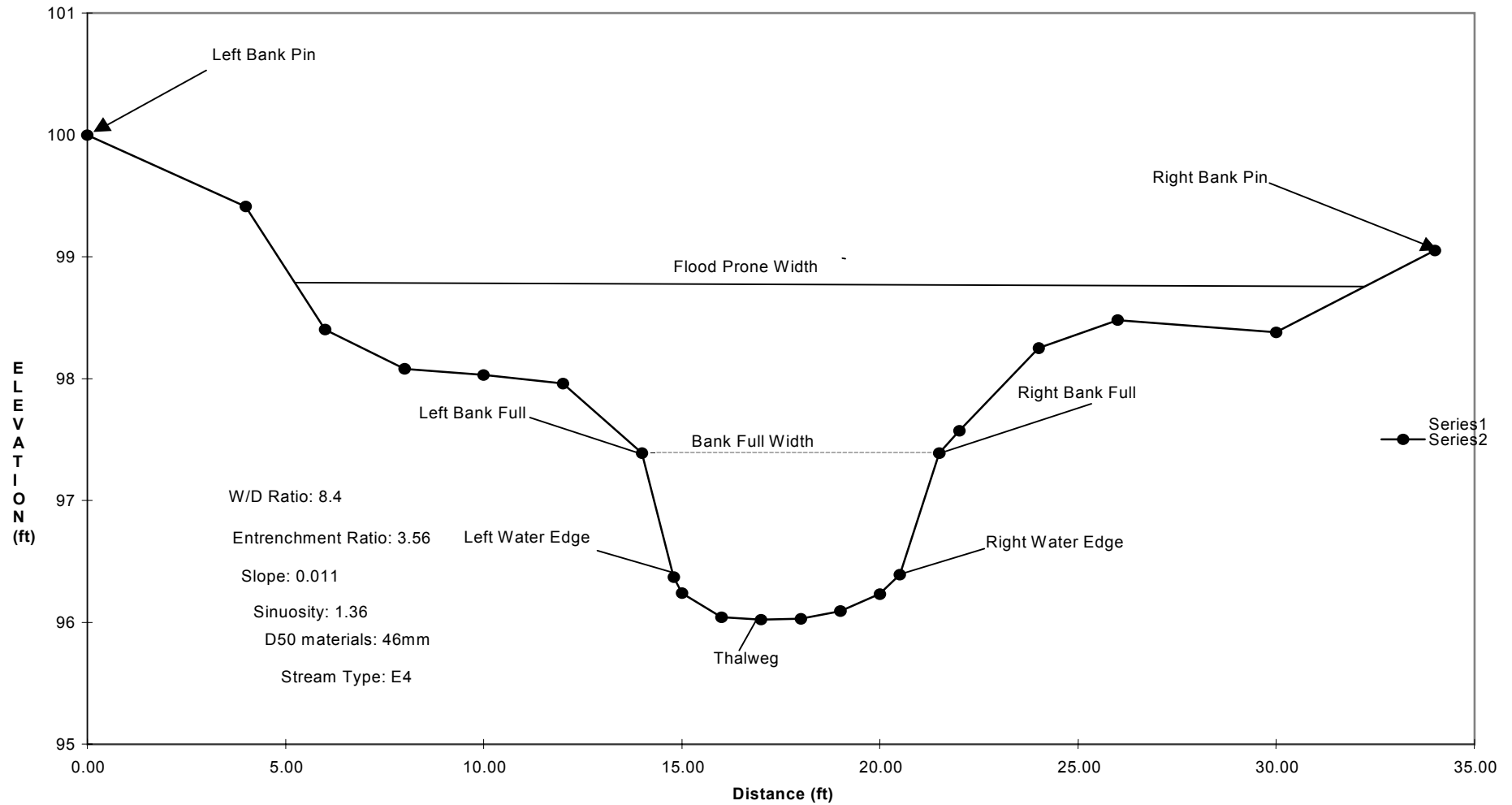


Each bar on the graph represents the 24-hour maximum temperature on each day (i.e. 21°C on 7/30/98).

Upper Rio Chamita Thermograph Site



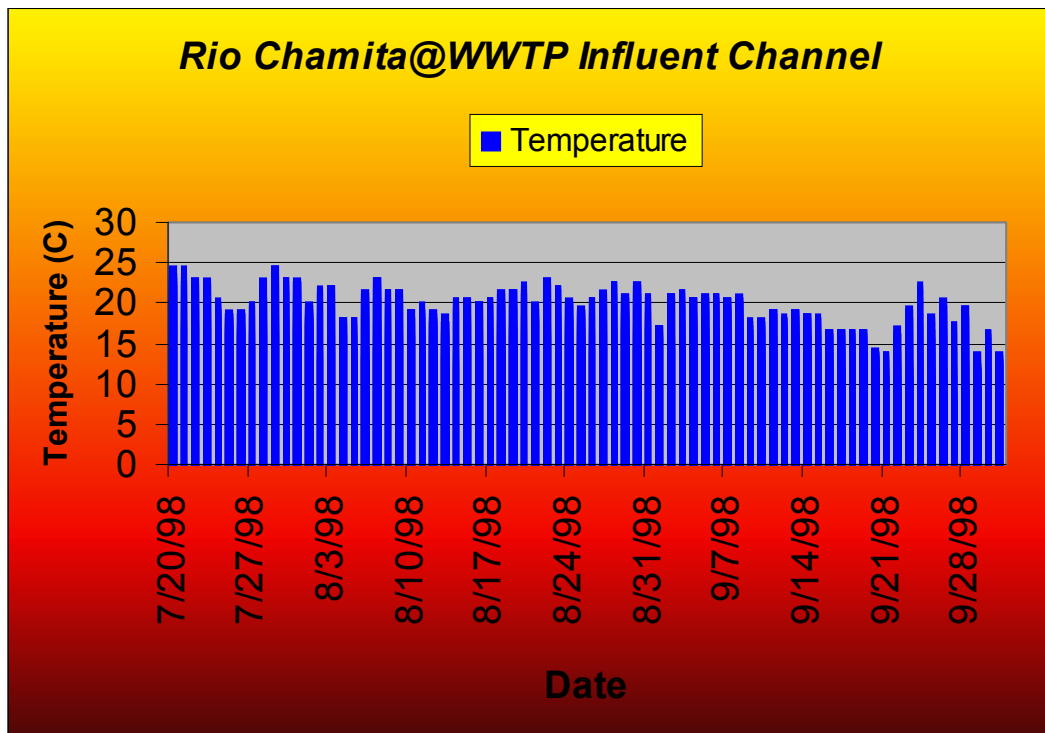
UPPER RIO CHAMITA CROSS-CHANNEL PROFILE



THALWAG = the thread of the deepest water; **SINUOSITY** = stream length/valley length or valley slope/channel slope; **ENTRENCHMENT RATIO** = the degree of vertical containment of a river channel (width of the flood prone area at an elevation twice the maximum bankfull depth/bankfull width; **W/D RATIO** = the shape of the channel cross-section (ratio of bankfull width/mean bankfull depth); **SLOPE** = slope of the water surface averaged for 20-30 channel widths

Lower Rio Chamita Thermograph Data

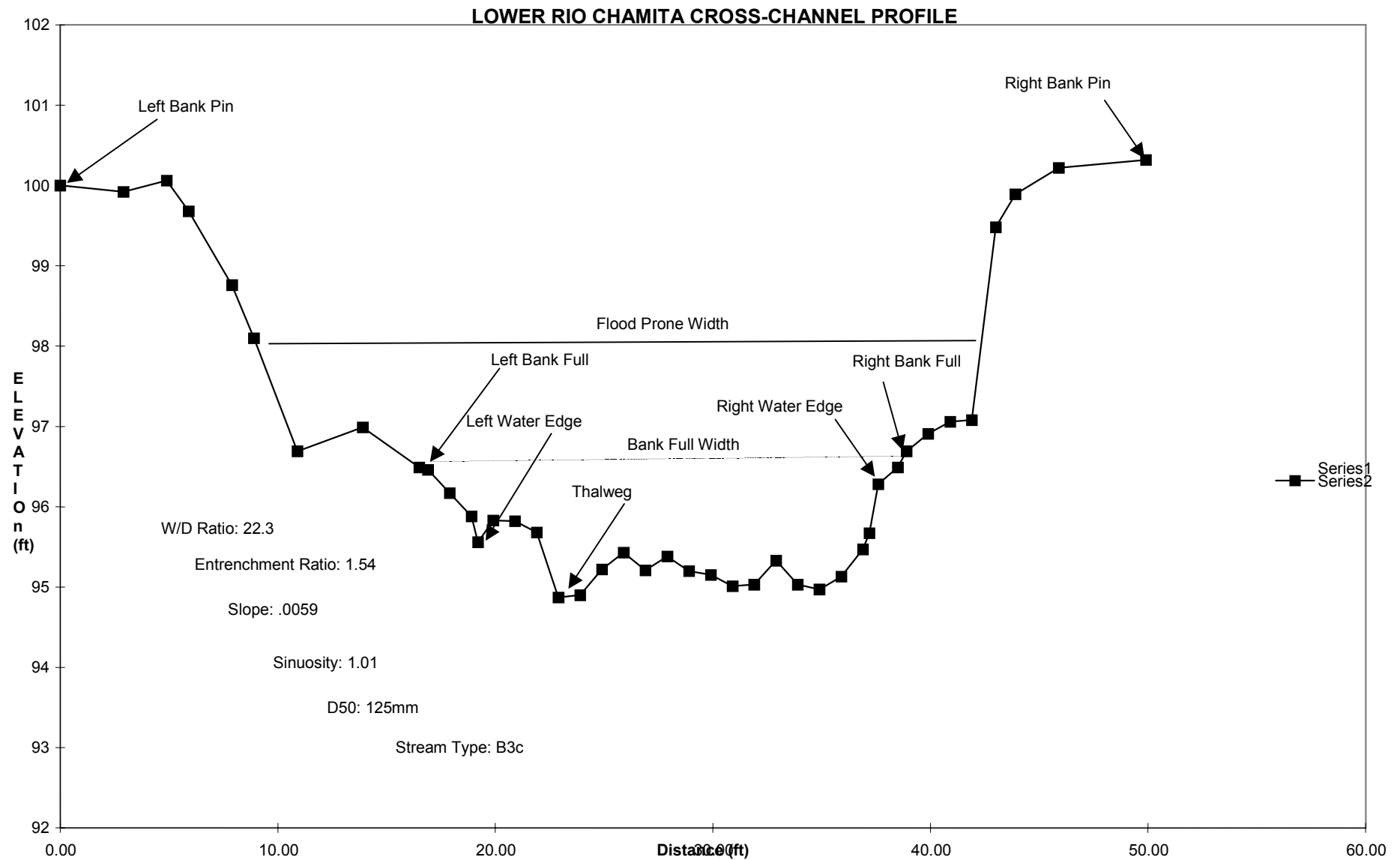
Total Readings	1750
Max. Temp.	24.5
# Values>20	254
% Values>20	14.5
Avg. Temp.	16.8
Min. Temp.	6.5
Variance	10.0



Each bar on the graph represents the 24-hour maximum temperature on each day (i.e. 22.5°C on 9/24/98).

Lower Rio Chamita Thermograph Site





THALWAG = the thread of the deepest water; **SINUOSITY** = stream length/valley length or valley slope/channel slope; **ENTRENCHMENT RATIO** = the degree of vertical containment of a river channel (width of the flood prone area at an elevation twice the maximum bankfull depth/bankfull width); **W/D RATIO** = the shape of the channel cross-section (ratio of bankfull width/mean bankfull depth); **SLOPE** = slope of the water surface averaged for 20-30 channel widths

Appendix B SSTEMP Model Outputs

Upper Rio Chamita

SSTEMP V3 6 08-30-1999 10:40:46

Run #1

1.54	Segment Inflow	cfs
57.380	Inflow Temperature	□F
1.54	Segment Outflow	cfs
50.000	Lateral Temperature	□F
6.000	Segment Length	mi
0.035	Manning's n	
8200.000	Elevation Upstream	ft
8107.000	Downstream	ft
7.000	Width's A Term	
0.200	B Term where $W = A * Q^{**}B$	
1.650	Thermal Gradient $j/m^2/s/c$	
78.000	Air Temperature	□F
12.000	Relative Humidity	%
8.000	Wind Speed	mph
85.000	Percent Possible Sun	%
686.91	Solar Radiation	Langley's
14.03	Daylight Length	hr
41.000	Segment Shading	%
50.000	Ground Temperature	□F
0.000	Dam at Inflow (Yes=1 No=0)	
Minimum 24-hour temperature 53.53□F		
Mean 24-hour temperature 62.59□F		
Maximum 24-hour temperature 71.66□F		

SSTEMP V3 6 08-30-1999 10:40:57

Run #2

1.54	Segment Inflow	cfs
57.380	Inflow Temperature	□F
1.54	Segment Outflow	cfs
50.000	Lateral Temperature	□F
6.000	Segment Length	mi
0.035	Manning's n	
8200.000	Elevation Upstream	ft
8107.000	Downstream	ft
7.000	Width's A Term	
0.200	B Term where $W = A * Q^{**}B$	

1.650	Thermal Gradient $j/m^2/s/c$	
78.000	Air Temperature	$^{\circ}F$
12.000	Relative Humidity	%
8.000	Wind Speed	mph
85.000	Percent Possible Sun	%
686.91	Solar Radiation	Langley's
14.03	Daylight Length	hr
46.000	Segment Shading	%
50.000	Ground Temperature	$^{\circ}F$
0.000	Dam at Inflow (Yes=1 No=0)	

Minimum 24-hour temperature	53.32 $^{\circ}F$
Mean 24-hour temperature	61.91 $^{\circ}F$
Maximum 24-hour temperature	70.50 $^{\circ}F$

SSTEMP V3 6 08-30-1999 10:41:12

Run #3

1.54	Segment Inflow	cfs
57.380	Inflow Temperature	$^{\circ}F$
1.54	Segment Outflow	cfs
50.000	Lateral Temperature	$^{\circ}F$
6.000	Segment Length	mi
0.035	Manning's n	
8200.000	Elevation Upstream	ft
8107.000	Downstream	ft
7.000	Width's A Term	
0.200	B Term where $W = A*Q^{**}B$	
1.650	Thermal Gradient $j/m^2/s/c$	
78.000	Air Temperature	$^{\circ}F$
12.000	Relative Humidity	%
8.000	Wind Speed	mph
85.000	Percent Possible Sun	%
686.91	Solar Radiation	Langley's
14.03	Daylight Length	hr
50.000	Segment Shading	%
50.000	Ground Temperature	$^{\circ}F$
0.000	Dam at Inflow (Yes=1 No=0)	

Minimum 24-hour temperature	53.16 $^{\circ}F$
Mean 24-hour temperature	61.36 $^{\circ}F$
Maximum 24-hour temperature	69.56 $^{\circ}F$

SSTEMP V3 6 08-30-1999 10:41:30

Run #4

1.54	Segment Inflow	cfs
57.380	Inflow Temperature	□F
1.54	Segment Outflow	cfs
50.000	Lateral Temperature	□F
6.000	Segment Length	mi
0.035	Manning's n	
8200.000	Elevation Upstream	ft
8107.000	Downstream	ft
7.000	Width's A Term	
0.200	B Term where $W = A * Q^{**}B$	
1.650	Thermal Gradient $j/m^2/s/c$	
78.000	Air Temperature	□F
12.000	Relative Humidity	%
8.000	Wind Speed	mph
85.000	Percent Possible Sun	%
686.91	Solar Radiation	Langleys
14.03	Daylight Length	hr
55.000	Segment Shading	%
50.000	Ground Temperature	□F
0.000	Dam at Inflow (Yes=1 No=0)	

Minimum 24-hour temperature	52.97□F
Mean 24-hour temperature	60.67□F
Maximum 24-hour temperature	68.36□F

SSTEMP V3 6 08-30-1999 10:41:34

Run #5

1.54	Segment Inflow	cfs
57.380	Inflow Temperature	□F
1.54	Segment Outflow	cfs
50.000	Lateral Temperature	□F
6.000	Segment Length	mi
0.035	Manning's n	
8200.000	Elevation Upstream	ft
8107.000	Downstream	ft
7.000	Width's A Term	
0.200	B Term where $W = A * Q^{**}B$	
1.650	Thermal Gradient $j/m^2/s/c$	
78.000	Air Temperature	□F
12.000	Relative Humidity	%
8.000	Wind Speed	mph

85.000	Percent Possible Sun	%
686.91	Solar Radiation	Langley's
14.03	Daylight Length	hr
56.000	Segment Shading	%
50.000	Ground Temperature	°F
0.000	Dam at Inflow (Yes=1 No=0)	

Minimum 24-hour temperature	52.93°F
Mean 24-hour temperature	60.53°F
Maximum 24-hour temperature	68.12°F

SSTEMP V3 6 08-30-1999 10:41:38

Run #6

1.54	Segment Inflow	cfs
57.380	Inflow Temperature	°F
1.54	Segment Outflow	cfs
50.000	Lateral Temperature	°F
6.000	Segment Length	mi
0.035	Manning's n	
8200.000	Elevation Upstream	ft
8107.000	Downstream	ft
7.000	Width's A Term	
0.200	B Term where $W = A \cdot Q^{**}B$	
1.650	Thermal Gradient $j/m^2/s/c$	
78.000	Air Temperature	°F
12.000	Relative Humidity	%
8.000	Wind Speed	mph
85.000	Percent Possible Sun	%
686.91	Solar Radiation	Langley's
14.03	Daylight Length	hr
57.000	Segment Shading	%
50.000	Ground Temperature	°F
0.000	Dam at Inflow (Yes=1 No=0)	

Minimum 24-hour temperature	52.90°F
Mean 24-hour temperature	60.39°F
Maximum 24-hour temperature	67.88°F

SSTEMP V3 6 08-30-1999 10:42:02

Run #7

1.54	Segment Inflow	cfs
57.380	Inflow Temperature	□F
1.54	Segment Outflow	cfs
50.000	Lateral Temperature	□F
6.000	Segment Length	mi
0.035	Manning's n	
8200.000	Elevation Upstream	ft
8107.000	Downstream	ft
7.000	Width's A Term	
0.200	B Term where $W = A * Q^{**}B$	
1.650	Thermal Gradient $j/m^2/s/c$	
78.000	Air Temperature	□F
12.000	Relative Humidity	%
8.000	Wind Speed	mph
85.000	Percent Possible Sun	%
686.91	Solar Radiation	Langley's
14.03	Daylight Length	hr
62.000	Segment Shading	%
50.000	Ground Temperature	□F
0.000	Dam at Inflow (Yes=1 No=0)	

Minimum 24-hour temperature	52.72□F
Mean 24-hour temperature	59.68□F
Maximum 24-hour temperature	66.64□F

Lower Rio Chamita

SSTEMP V3 6 08-30-1999 14:44:38

Run #1

1.54	Segment Inflow	cfs
62.240	Inflow Temperature	□F
3.40	Segment Outflow	cfs
52.000	Lateral Temperature	□F
6.000	Segment Length	mi
0.035	Manning's n	
8107.000	Elevation Upstream	ft
7716.000	Downstream	ft
22.000	Width's A Term	
0.200	B Term where $W = A * Q^{**}B$	
1.650	Thermal Gradient $j/m^2/s/c$	
78.000	Air Temperature	□F

12.000	Relative Humidity	%
8.000	Wind Speed	mph
85.000	Percent Possible Sun	%
687.46	Solar Radiation	Langley's
14.03	Daylight Length	hr
36.000	Segment Shading	%
52.000	Ground Temperature	°F
0.000	Dam at Inflow (Yes=1 No=0)	

Minimum 24-hour temperature	52.11°F
Mean 24-hour temperature	62.59°F
Maximum 24-hour temperature	73.08°F

SSTEMP V3 6 08-30-1999 14:44:53

Run #2

1.54	Segment Inflow	cfs
62.240	Inflow Temperature	°F
3.40	Segment Outflow	cfs
52.000	Lateral Temperature	°F
6.000	Segment Length	mi
0.035	Manning's n	
8107.000	Elevation Upstream	ft
7716.000	Downstream	ft
22.000	Width's A Term	
0.200	B Term where $W = A * Q^{**B}$	
1.650	Thermal Gradient $j/m^2/s/c$	
78.000	Air Temperature	°F
12.000	Relative Humidity	%
8.000	Wind Speed	mph
85.000	Percent Possible Sun	%
687.46	Solar Radiation	Langley's
14.03	Daylight Length	hr
40.000	Segment Shading	%
52.000	Ground Temperature	°F
0.000	Dam at Inflow (Yes=1 No=0)	

Minimum 24-hour temperature	51.99°F
Mean 24-hour temperature	62.09°F
Maximum 24-hour temperature	72.18°F

SSTEMP V3 6 08-30-1999 14:45:17

Run #3

1.54	Segment Inflow	cfs
62.240	Inflow Temperature	□F
3.40	Segment Outflow	cfs
52.000	Lateral Temperature	□F
6.000	Segment Length	mi
0.035	Manning's n	
8107.000	Elevation Upstream	ft
7716.000	Downstream	ft
22.000	Width's A Term	
0.200	B Term where $W = A * Q^{**}B$	
1.650	Thermal Gradient $j/m^2/s/c$	
78.000	Air Temperature	□F
12.000	Relative Humidity	%
8.000	Wind Speed	mph
85.000	Percent Possible Sun	%
687.46	Solar Radiation	Langleys
14.03	Daylight Length	hr
45.000	Segment Shading	%
52.000	Ground Temperature	□F
0.000	Dam at Inflow (Yes=1 No=0)	

Minimum 24-hour temperature	51.86□F
Mean 24-hour temperature	61.45□F
Maximum 24-hour temperature	71.04□F

SSTEMP V3 6 08-30-1999 14:45:59

Run #4

1.54	Segment Inflow	cfs
62.240	Inflow Temperature	□F
3.40	Segment Outflow	cfs
52.000	Lateral Temperature	□F
6.000	Segment Length	mi
0.035	Manning's n	
8107.000	Elevation Upstream	ft
7716.000	Downstream	ft
22.000	Width's A Term	
0.200	B Term where $W = A * Q^{**}B$	
1.650	Thermal Gradient $j/m^2/s/c$	
78.000	Air Temperature	□F
12.000	Relative Humidity	%
8.000	Wind Speed	mph

85.000	Percent Possible Sun	%
687.46	Solar Radiation	Langley's
14.03	Daylight Length	hr
50.000	Segment Shading	%
52.000	Ground Temperature	°F
0.000	Dam at Inflow (Yes=1 No=0)	

Minimum 24-hour temperature	51.74°F
Mean 24-hour temperature	60.80°F
Maximum 24-hour temperature	69.86°F

SSTEMP V3 6 08-30-1999 14:46:18

Run #5

1.54	Segment Inflow	cfs
62.240	Inflow Temperature	°F
3.40	Segment Outflow	cfs
52.000	Lateral Temperature	°F
6.000	Segment Length	mi
0.035	Manning's n	
8107.000	Elevation Upstream	ft
7716.000	Downstream	ft
22.000	Width's A Term	
0.200	B Term where $W = A * Q^{**}B$	
1.650	Thermal Gradient $j/m^2/s/c$	
78.000	Air Temperature	°F
12.000	Relative Humidity	%
8.000	Wind Speed	mph
85.000	Percent Possible Sun	%
687.46	Solar Radiation	Langley's
14.03	Daylight Length	hr
55.000	Segment Shading	%
52.000	Ground Temperature	°F
0.000	Dam at Inflow (Yes=1 No=0)	

Minimum 24-hour temperature	51.63°F
Mean 24-hour temperature	60.15°F
Maximum 24-hour temperature	68.66°F

SSTEMP V3 6 08-30-1999 14:46:31

Run #6

1.54	Segment Inflow	cfs
62.240	Inflow Temperature	□F
3.40	Segment Outflow	cfs
52.000	Lateral Temperature	□F
6.000	Segment Length	mi
0.035	Manning's n	
8107.000	Elevation Upstream	ft
7716.000	Downstream	ft
22.000	Width's A Term	
0.200	B Term where $W = A * Q^{**}B$	
1.650	Thermal Gradient $j/m^2/s/c$	
78.000	Air Temperature	□F
12.000	Relative Humidity	%
8.000	Wind Speed	mph
85.000	Percent Possible Sun	%
687.46	Solar Radiation	Langley's
14.03	Daylight Length	hr
58.000	Segment Shading	%
52.000	Ground Temperature	□F
0.000	Dam at Inflow (Yes=1 No=0)	

Minimum 24-hour temperature	51.57□F
Mean 24-hour temperature	59.75□F
Maximum 24-hour temperature	67.92□F

SSTEMP V3 6 08-30-1999 14:46:57

Run #7

1.54	Segment Inflow	cfs
62.240	Inflow Temperature	□F
3.40	Segment Outflow	cfs
52.000	Lateral Temperature	□F
6.000	Segment Length	mi
0.035	Manning's n	
8107.000	Elevation Upstream	ft
7716.000	Downstream	ft
22.000	Width's A Term	
0.200	B Term where $W = A * Q^{**}B$	
1.650	Thermal Gradient $j/m^2/s/c$	
78.000	Air Temperature	□F
12.000	Relative Humidity	%
8.000	Wind Speed	mph

85.000	Percent Possible Sun	%
687.46	Solar Radiation	Langley's
14.03	Daylight Length	hr
63.000	Segment Shading	%
52.000	Ground Temperature	°F
0.000	Dam at Inflow (Yes=1 No=0)	

Minimum 24-hour temperature	51.49°F
Mean 24-hour temperature	59.08°F
Maximum 24-hour temperature	66.68°F

Appendix C

Critical Low Flow Model Outputs

Estimated 4Q3 flow for Upper Rio Chamita

It is often necessary to calculate a critical flow for a portion of a watershed where there is no stage gage. This can be accomplished by applying one of two formulas developed by the USGS. One formula (Waltemeyer 1987) is recommended when the ratio between the two watershed areas is between 0.5 and 1.5. The other formula, to be used when the watershed ratio is outside this range, is a regression formula also developed by the USGS (Borland 1970).

Where:

- A_g = Drainage area above the gage in question
- A_u = Watershed size above the area of interest
- P_a = Mean October through April precipitation in inches
- R = Ratio of $Q_{4/3}$ / $Q_{7/2}$

- 1) The nearest gage to the point of interest is the Rio Chama at La Puente (08284100). The drainage area above this gage (A_g) is 480 mi². The watershed above the area of interest (A_u) is 11 mi². The ratio of water shed size (11/480) is 0.02. Using guidelines recommended by USGS when this value is less than 0.5 we apply the formula as shown in step 2.

$$\begin{aligned}A_u &= 11 \text{ mi}^2 \\P_a &= 13\end{aligned}$$

- 2) Applying the formula the calculated 7Q2 is
$$\begin{aligned}Q_{7/2} &= 1.36 \times 10^{-4} \times (A_u)^{.566} \times (P_a)^{3.22} \\Q_{7/2} &= 1.36 \times 10^{-4} \times (11)^{.566} \times (13)^{3.22} \\Q_{7/2} &= 2.0 \text{ cfs}\end{aligned}$$

- 3) Multiply the ratio factor from step 1 (0.02) by the 7Q2 flow calculated in step 2 (2.0 cfs)

$$2.0 \text{ cfs} \times 0.02 = .04$$

- 4) The 1-day, 3-day, and 7-day low flow events are shown on the attached table. The $Q_{4/3}$ low flow is 17 cfs. The $Q_{7/2}$ is 22 cfs

$$\text{The ratio of } Q_{4/3} (17 \text{ cfs}) / Q_{7/2} (22 \text{ cfs}) \quad R = 0.77.$$

- 5) Multiplying the ratio(0.77) from step 4 times the $Q_{7/2}$ flow (2.0 cfs) in step 2 we get:

$$\begin{aligned}Q_{4/3(\text{est})} &= R (Q_{7/2}) \\Q_{4/3(\text{est})} &= 0.77 (2.0 \text{ cfs}) \\Q_{4/3(\text{est})} &= \mathbf{1.54 \text{ cfs}}\end{aligned}$$

Model verification

In order to validate the model, the Log Pearson Type III $Q_{4/3}$ based on empirical data from the Rio Chama at La Puente (08284100) gage was calculated using Hydrotech® software.

$$\begin{aligned}A_g &= 480 \text{ mi}^2 \\P_a &= 13 \text{ in} \\R &= 0.77 \\Q_{7/2} &= 1.36 \times 10^{-4} \times (A_g)^{.566} \times (P_a)^{3.22} \\Q_{7/2} &= 1.36 \times 10^{-4} \times (480)^{.566} \times (13)^{3.22} \\Q_{7/2} &= 17.3 \text{ cfs} \\Q_{4/3(\text{est})} &= R (Q_{7/2}) \\Q_{4/3(\text{est})} &= 0.77 (17.3 \text{ cfs}) \\Q_{4/3(\text{est})} &= 13.3 \text{ cfs}\end{aligned}$$

The formula estimated value of 13.3 cfs and the statistically derived value 19.2 cfs are then compared to calculate a % error between the estimated and statistically derived values.

$$\begin{aligned}\% \text{ Error} &= ((Q_{4/3(\text{est})} - Q_{4/3}) / Q_{7/2}) * 100 \\ \% \text{ Error} &= ((13.3 \text{ cfs} - 19.2 \text{ cfs}) / 19.2 \text{ cfs}) * 100 \\ \% \text{ Error} &= -30.7 \%\end{aligned}$$

Estimated 4Q3 flow for Lower Rio Chamita

It is often necessary to calculate a critical flow for a portion of a watershed where there is no stage gage. This can be accomplished by applying one of two formulas developed by the USGS. One formula (Waltemeyer 1987) is recommended when the ratio between the two watershed areas is between 0.5 and 1.5. The other formula, to be used when the watershed ratio is outside this range, is a regression formula also developed by the USGS (Borland 1970).

Where:

- A_g = Drainage area above the gage in question
- A_u = Watershed size above the area of interest
- P_a = Mean October through April precipitation in inches
- R = Ratio of $Q_{4/3}$ / $Q_{7/2}$

- 1) The nearest gage to the point of interest is the Rio Chama at La Puente (08284100). The drainage area above this gage (A_g) is 480 mi². The watershed above the area of interest (A_u) is 42 mi². The ratio of water shed size (42/480) is 0.09. Using guidelines recommended by USGS when this value is less than 0.5 we apply the formula as shown in step 2.

$$A_u = 42 \text{ mi}^2$$
$$P_a = 13$$

- 2) Applying the formula the calculated 7Q2 is
$$Q_{7/2} = 1.36 \times 10^{-4} \times (A_u)^{.566} \times (P_a)^{3.22}$$
$$Q_{7/2} = 1.36 \times 10^{-4} \times (42)^{.566} \times (13)^{3.22}$$
$$Q_{7/2} = 4.4 \text{ cfs}$$

- 3) Multiply the ratio factor from step 1 (0.09) by the 7Q2 flow calculated in step 2 (4.4 cfs)
$$4.4 \text{ cfs} \times 0.09 = .40$$

- 4) The 1-day, 3-day, and 7-day low flow events are shown on the attached table. The $Q_{4/3}$ low flow is 17 cfs. The $Q_{7/2}$ is 22 cfs

$$\text{The ratio of } Q_{4/3} (17 \text{ cfs}) / Q_{7/2} (22 \text{ cfs}) \quad R = 0.77.$$

- 5) Multiplying the ratio(0.77) from step 4 times the $Q_{7/2}$ flow (4.4 cfs) in step 2 we get:

$$Q_{4/3(\text{est})} = R (Q_{7/2})$$
$$Q_{4/3(\text{est})} = 0.77 (4.4 \text{ cfs})$$
$$Q_{4/3(\text{est})} = 3.4 \text{ cfs}$$

Model verification

In order to validate the model, the Log Pearson Type III $Q_{4/3}$ based on empirical data from the Rio Chama at La Puente (08284100) gage was calculated using Hydrotech® software.

$$\begin{aligned}
 A_g &= 480 \text{ mi}^2 \\
 P_a &= 13 \text{ in} \\
 R &= 0.77 \\
 Q_{7/2} &= 1.36 \times 10^{-4} \times (A_g)^{.566} \times (P_a)^{3.22} \\
 Q_{7/2} &= 1.36 \times 10^{-4} \times (480)^{.566} \times (13)^{3.22} \\
 Q_{7/2} &= 17.3 \text{ cfs} \\
 Q_{4/3(\text{est})} &= R (Q_{7/2}) \\
 Q_{4/3(\text{est})} &= 0.77 (17.3 \text{ cfs}) \\
 Q_{4/3(\text{est})} &= 13.3 \text{ cfs}
 \end{aligned}$$

The formula estimated value of 13.3 cfs and the statistically derived value 19.2 cfs are then compared to calculate a % error between the estimated and statistically derived values.

$$\begin{aligned}
 \% \text{ Error} &= ((Q_{4/3(\text{est})} - Q_{4/3}) / Q_{7/2}) * 100 \\
 \% \text{ Error} &= ((13.3 \text{ cfs} - 19.2 \text{ cfs}) / 19.2 \text{ cfs}) * 100 \\
 \% \text{ Error} &= -30.7 \%
 \end{aligned}$$

Appendix D

Public Comments

References Cited

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